PATENT SPECIFICATION

1,131,293

DRAWINGS ATTACHED.

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1,131,293

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COMPLETE SPECIFICATION.

Optical Sighting Apparatus.

We, SPERRY RAND LIMITED, a British Company, of Remington House, 65, Holborn Viaduct, London, E.C.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention is concerned with Optical Sighting Apparatus for causing an image to be visible superimposed on an external scene.

One example of such apparatus is in head-up display systems for aircraft, in which an indication of the position and orientation of a landing runway based on information derived mainly from the aircraft ILS system can be displayed to a pilot, superimposed on his view of the actual runway, so that he can make his landing approach with confidence in conditions of poor or intermittent visibility. The display may, of course, also include information as to aircraft attitude, air-speed, etc. to avoid the necessity for the pilot lowering his eyes to the instrument panel under these conditions.

According to the present invention, optical sighting apparatus for causing an image to appear superimposed on an external scene includes an image source, a concave mirror, a projection lens substantially at the centre of curvature of the mirror and arranged to produce an image of the source at the principal focus of the mirror, and a partially-reflecting inclined plane mirror disposed between the concave mirror and the lens so as to enable a virtual image of the source produced by the mirror at infinity to be viewed against an external scene.

The exit pupil of an optical system of this kind is the image produced after reflection in the concave and partially-reflecting mirrors of one or more of the apertures of the optical system constituting the projection lens. This is a real image which in suitable cases can be arranged to fall well outside the physical bounds of the system. In the application mentioned to the head-up display system, the exit pupil can conveniently be located at or close to the position of the pilot's eyes. Furthermore, since the exit pupil is the same size or slightly larger than the aperture of the projections lens, an exit pupil of reasonable size (e.g. 3 inch diameter) can be obtained without the cost and weight of an excessively large diameter lens, so enabling the pilot to have a reasonable range of head movement without losing his view of the image.

Particularly in aircraft where it is required to get the apparatus into a minimum physical space, it may be conventient to fold the optical system by the use of further plane mirrors. In such a case, of course, account is taken of the folding of the optical path in determining the position of the lens and mirror.

The image source may conveniently be the screen of a cathode-ray tube and in the application of the invention to aircraft head-up display systems the cathode-ray tube may be fed with signals from a generator arranged to generate an image of a runway whose position relative to the aircraft is calculated from information obtained from the ILS receiver. The image may be arranged to indicate the actual orientation of the runway and may be arranged to vary inversely in size with its range from the aircraft.

The invention will be further described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a longitudinal sectional elevation of an aircraft cock-pit showing the position of the pilot;

Figure 2 is a graphical representation of some of the variable parameters involved in the application of the invention, and

Figure 3 is a simplified diagram of the optical arrangement of Figure 1.

Figure 1 shows the cock-pit of an aircraft with a pilot 1 viewing the scene before him through the wind-shield 2. In front of the pilot is the instrument panel 3 and the flying controls (which are not shown in the drawing).

A mirror mounting 4 is attached to the roof of the cock-pit by a bracket incorporating adjusting screws 5 and carries a concave mirror 6 metallised on its front surface and facing downwards towards the instrument panel. The mirror mounting 4 also carries a folding bracket 7 from which is supported a glass plate 8 lightly metallised on one surface to form a partially-reflecting mirror having about 80% transmission and 20% reflection.

A cathode-ray tube 9 is mounted transversely at the top of the instrument panel 3 with its screen 10 facing a mirror 11 at an angle of 45°, positioned so as to reflect light from the screen 10 through a projection lens system 12 in the general direction of the pilot. An inclined mirror 13 metallised on its front surface reflects this light upwards towards the concave mirror.

The cathode-ray tube 9, lens system 12 and mirror 13 are contained in a blackened metal box, the front surface of which is prolonged to form a tray 14 surrounding the mirror 13, and which acts as a glare-shield, shielding the pilot's eyes from any direct light from the cathode-ray tube or lens.

In Figure 3 the same parts as those in Figure 1 have been given the same reference numerals, but it will be seen that mirrors 11, 13 and 8 and their bending effects have been omitted so that the optical co-operation of the remaining parts is more apparent.

The composite lens 12 forms a real image 15 of the cathode ray tube screen at a position in space which lies in the focal surface of spherical mirror 6, i.e. at a distance F_M from the mirror where F_M is half the radius of curvature of the mirror. The mirror therefore forms a virtual image at infinity of real image 15, which virtual image is viewed by the pilot 1 through semi-reflecting mirror 8 (Figure 1(superimposed on his view through the wind-screen 2.

The use of the spherical mirror for collimating the light permits accurate collimation over an area giving the pilot a comparatively large field of view. Precision of collimation depends on the fact that any line through the centre of curvature of the mirror is an optical axis of symmetry, and little or no spherical aberration is introduced by the mirror for a ray of light along such an axis. The aberration increases with the cube of the minimum distance by which the ray of light misses the centre of curvature.

The relay lens 12 is therefore placed close to the centre of curvature 16 of the mirror so that since the only rays of light reaching the mirror are ones which have passed through the lens, the distance by which they have missed the centre of curvature is limited by the diameter of the lens. The spherical aberration is therefore limited.

The exit pupil D of the system is the real image of the lens aperture formed by the mirror 6 at a distance V from the mirror. The exit pupil D in practice defines an area through which all the rays of light from mirror 6 pass and is therefore the position at which a viewer has the widest angle of view possible. Since the rays of light from mirror 6 are bent by mirror 8, the exit pupil D occurs in the plane of the eyes of the pilot 1 seen in Figure 1. In one arrangement for instance using a three inch diameter lens a four inch diameter exit pupil is formed. The pilot therefore can move his head from side to side or up and down within the exit pupil without losing binocular vision of the cathode ray tube image.

In an aircraft cock-pit the space available for the installation of the optical system is frequently limited, so that there may be little choice for the dimension V (from the spherical mirror 6 by way of mirror 8 to the pilot's eyes) and dimension U (from the lens 12 to the mirror 6). For a cathode-ray tube of diameter 2.96 inch and a relay lens of diameter 2.13 inch, Figure 2 shows curves of U against V for chosen focal lengths between $F_M=8$ and 11 of the spherical mirror. Therefore if the available dimensions of U and V are known, the necessary focal length can be approximately determined from the curves. For a particular relay lens, the dimensions of U and V fix the size of the exit pupil and this is also plotted in Figure 2 for particular exit pupil diameters between 2 inches and 4.5 inches. The dotted lines in Figure 2 give the horizontal field of view available from the cathode ray tube.

Two examples for actual aircraft are shown in Figure 2. The VC 10 aircraft cock-pit affords values of U and V of 13.8 inches and 25.8 inches respectively. As seen in Figure 2 this fixes the necessary focal length of spherical mirror at $F_M=9$, and gives an exit pupil D of about 4 inches diameter and an angular field of view of 25°.

For the Trident aircraft, the values of U and V are such that F_M is about 9.4, exit pupil D about 3.2 inch and the field of view about 33°.

It will be appreciated that both these examples give excellent fields of view with reasonable freedom for movement of the pilot's head. Other sizes of cathode ray tubes and relay lenses will of course alter the performance of the system.

In operation, signals obtained from the aircraft's ILS receiver are fed to time-base generating circuits (not shown) to form on the cathode ray tube screen 10, an image representing the position and orientation of a landing strip. The size of the image may be caused to vary inversely with the range from the aircraft to the landing strip.

Bias signals are applied to the deflecting electrodes of the cathode-ray tube 9 derived from the aircraft compass system and gyro vertical to stabilise the image in space so that it continuously corresponds with the actual position of the runway as computed from the ILS signals and the aircraft attitude.

The pilot sees the image superimposed on the real world runway so that for instance in conditions of poor or intermittent visibility he can change substantially instantaneously from instrument to visual flying and back.

WHAT WE CLAIM IS:—

1. Optical sighting apparatus for causing an image to appear superimposed on an external scene, including an image source, a concave mirror, a projection lens substantially at the centre of curvature of the mirror and arranged to produce an image of the source at the principal focus of the mirror and a partially-reflecting inclined plane mirror disposed between the concave mirror and the lens so as to enable a virtual image of the source produced by the mirror at infinity to be viewed by an observer against an external scene.

2. Optical sighting apparatus as claimed in claim 1, wherein the exit pupil defined by the formation of an image of the projection lens by the concave mirror after reflection from the plane mirror is located at the position of the observer's eyes.

3. Optical sighting apparatus as claimed in Claim 1 or Claim 2 contained in two separately mounted parts, one comprising the image source and the projection lens and the other the concave mirror and the partially-reflecting plane mirror.

4. A head-up display system for an aircraft comprising optical sighting apparatus as claimed in any of claims 1 to 3, wherein said image source carries information relating to the position of a landing runway and the virtual image of the source is positioned to be seen by the aircraft's pilot against the aircraft windshield.

5. A head-up display system as claimed in claim 4, wherein said image source is a cathode-ray tube positioned in or adjacent the instrument panel of the aircraft and said concave mirror is positioned adjacent the roof of the cock-pit.

6. A head-up display system as claimed in claim 5, wherein said partially-reflecting mirror is mounted on a folding bracket whereby it is suspended from the roof of the cock-pit and can be folded up against the roof when not required.

7. A head-up display system as claimed in claim 5 or claim 6 wherein said cathode-ray tube is positioned with its axis running parallel to the instrument panel and one plane mirror is positioned at an angle of 45° to its screen so as to reflect light from the screen through the projection lens, and another plane mirror is positioned in the path of the light from the projection lens to direct it up toward the said concave mirror.

8. A head-up display system as claimed in any of claims 4 to 7, wherein the image source has a diameter of about 3 inches, the projection lens has a diameter of about 2 inches, the concave mirror has a focal length of about 9 inches, the exit pupil has a diameter of more than 3 inches and the observer's field of view is greater than 25°.

9. A head-up display system substantially as described hereinbefore with reference to the drawings accompanying the Specification.

For the Applicants,
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Chartered Patent Agent.

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1131293 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

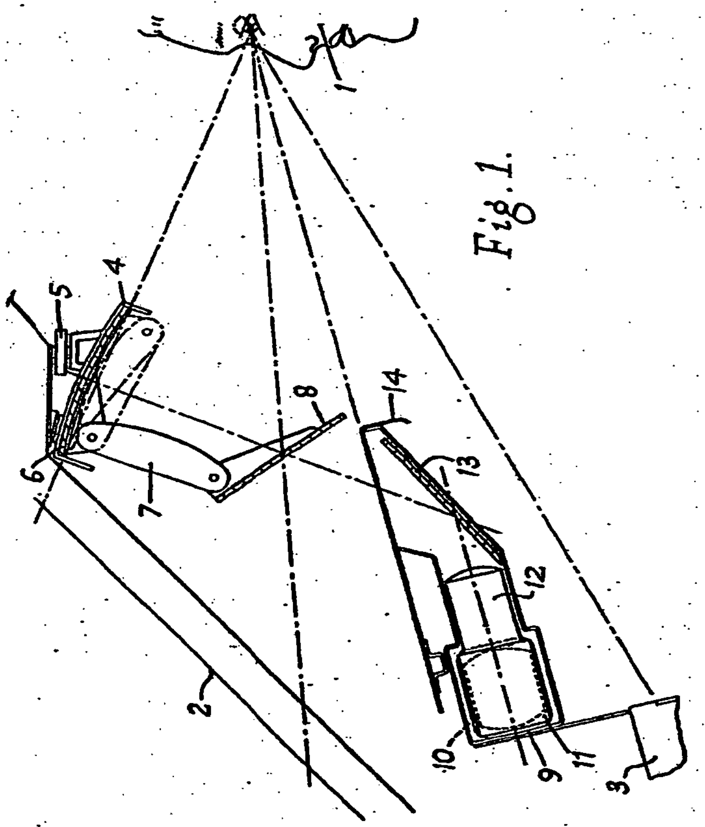
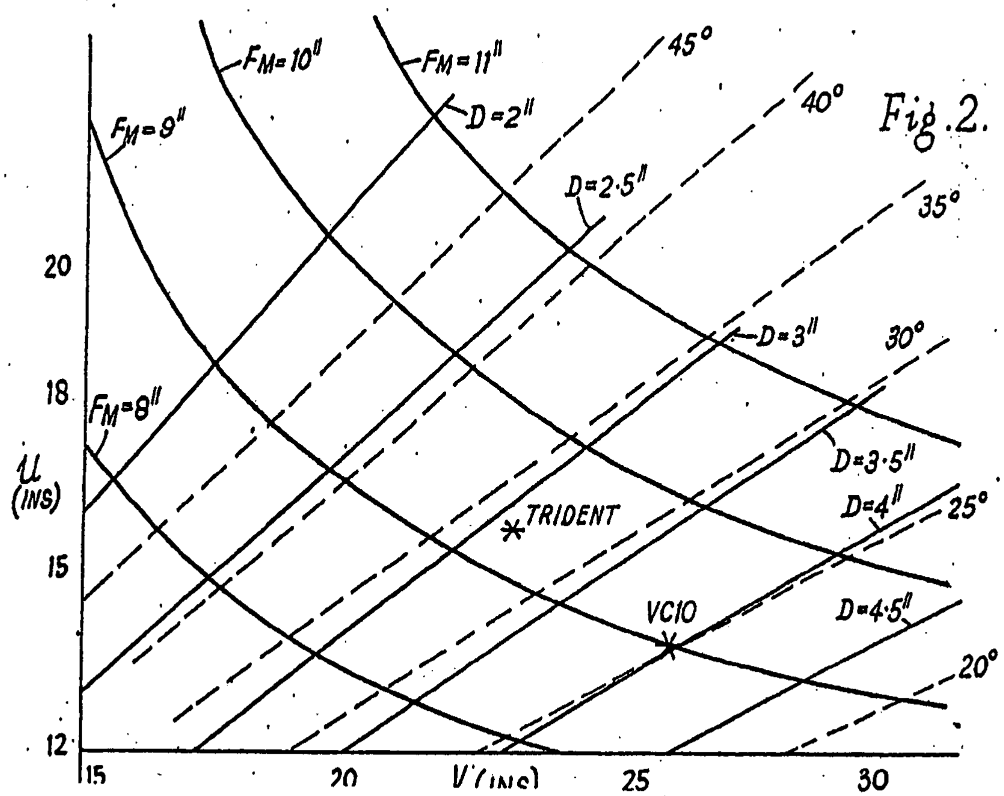


Fig. 1.



$F_M = 9''$
$F_M = 10''$
$F_M = 11''$
$F_M = 8''$
$D = 2''$
$D = 2{\cdot}5''$
$D = 3''$
$D = 3{\cdot}5''$
$D = 4''$
$D = 4{\cdot}5''$
45°
40°
35°
30°
25°
20°
TRIDENT
VC10
u (INS)
20
18
15
12
V (INS)
15
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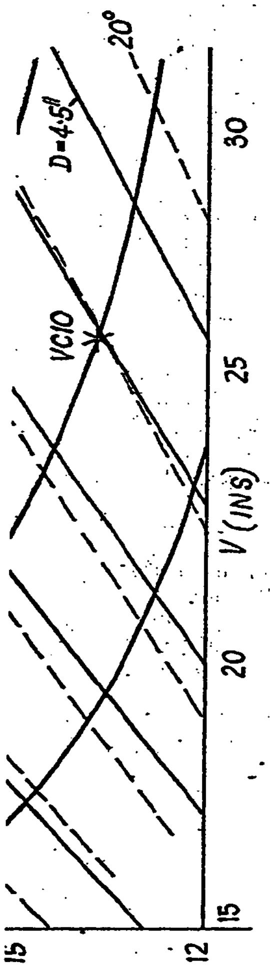
25
30

Fig. 2.

1131293 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 2 & 3



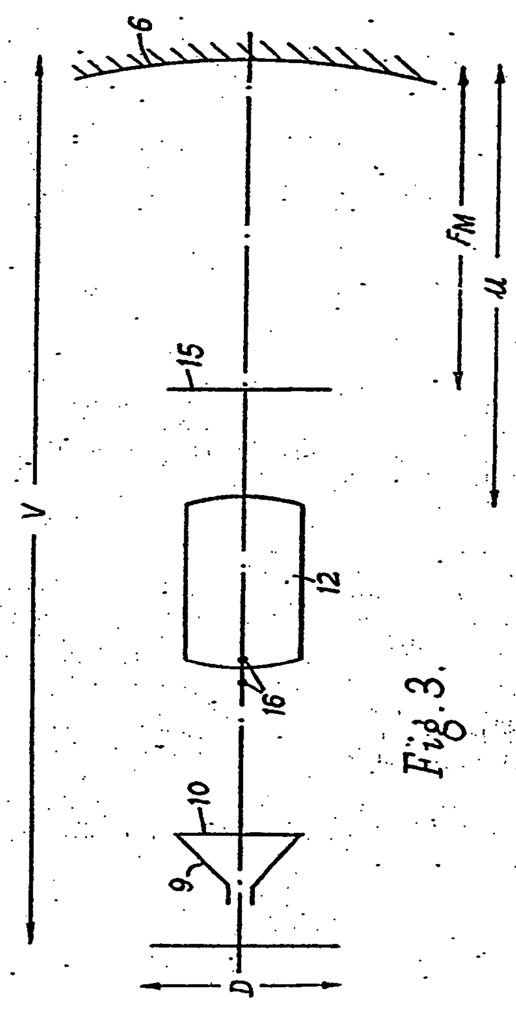


Fig. 3.

1131293 COMPLETE SPECIFICATION
3 SHEETS This drawing is a reproduction of the Original on a reduced scale
Sheets 2 & 3

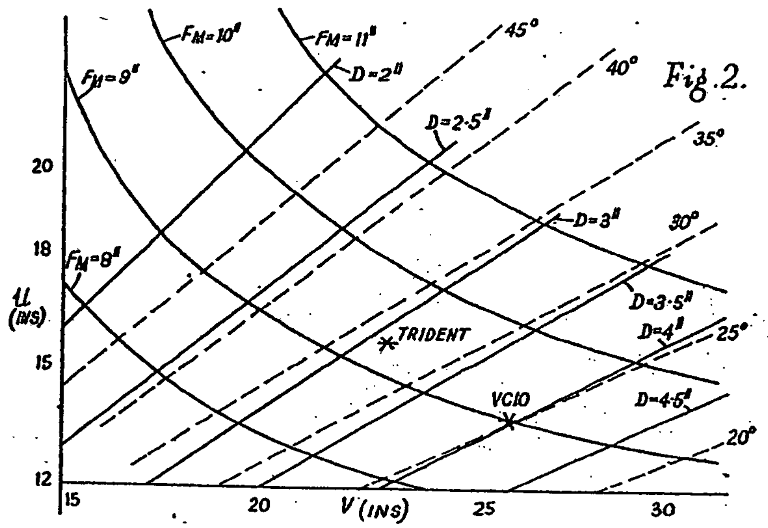


Fig. 2.

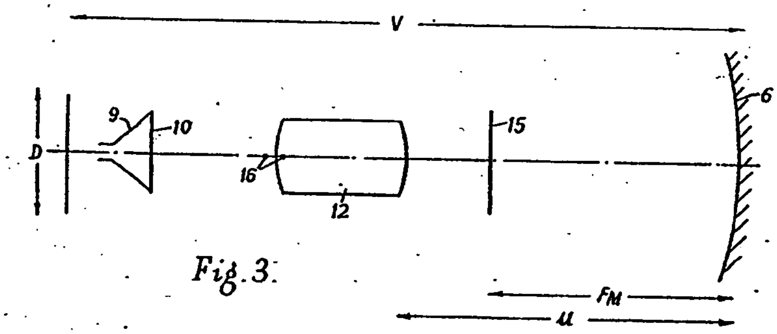
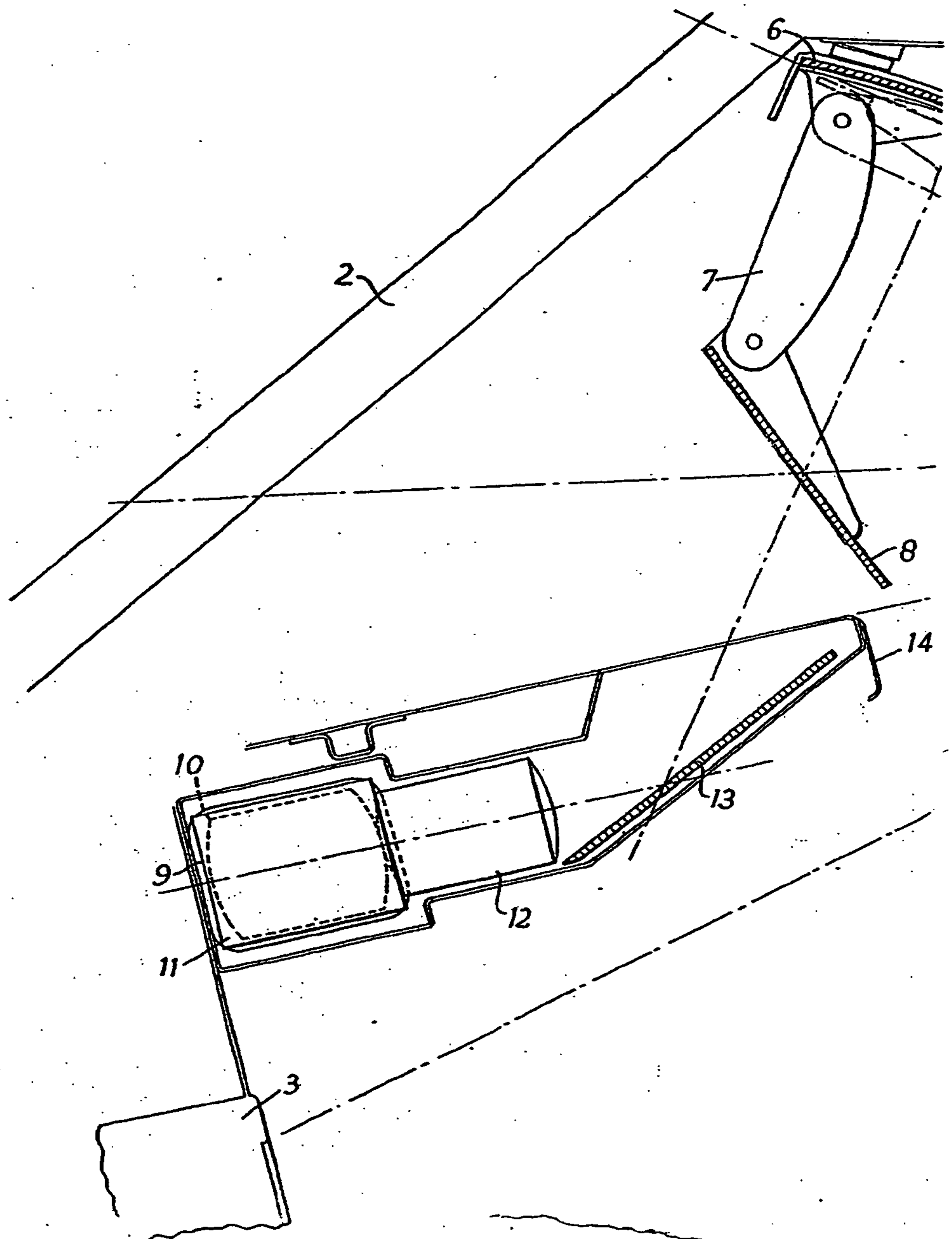


Fig. 3.


6
2
7
8
14
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11
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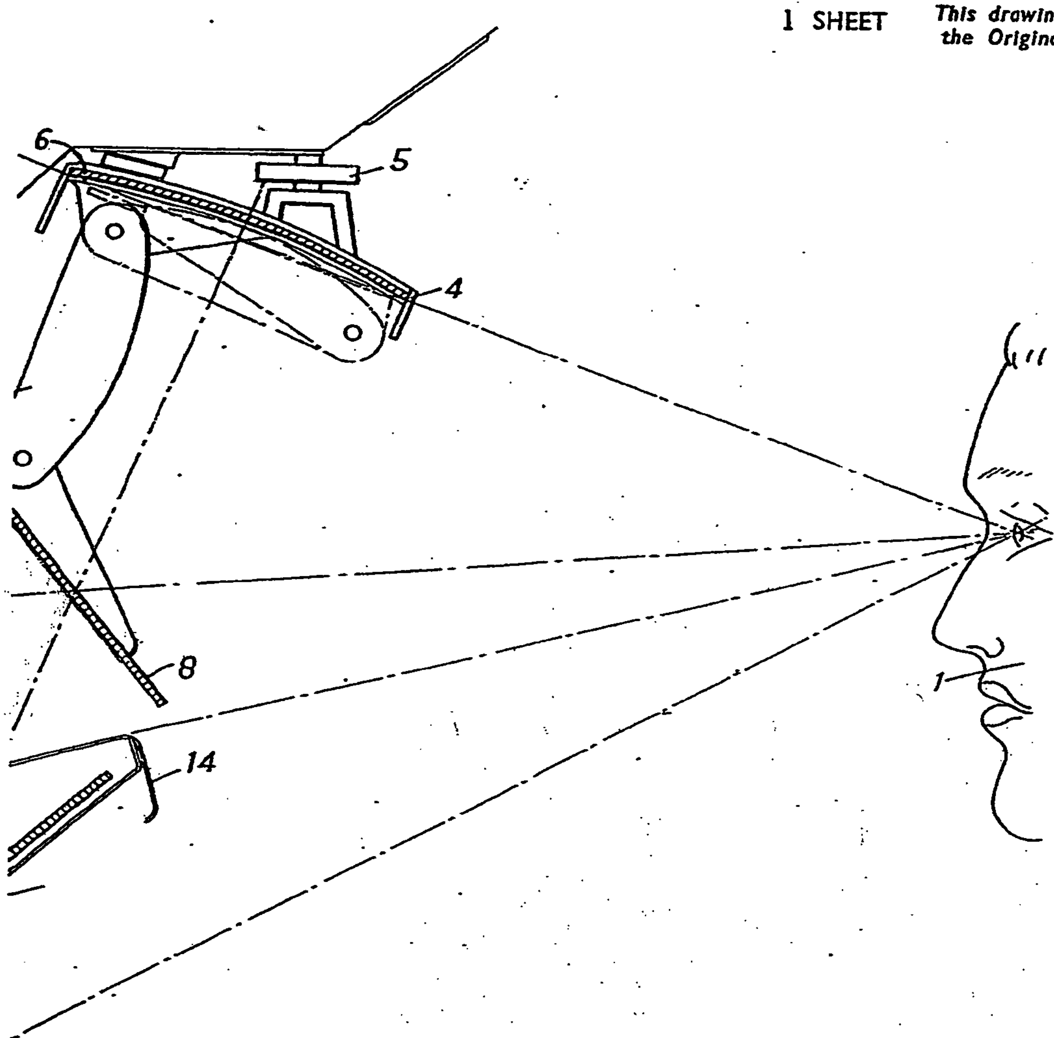
1131293 PROVISIONAL SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*



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